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Efficient topology control algorithms for ad hoc networks

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Efficient Topology Control Algorithms For Ad Hoc Networks

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Abstract

An Ad-hoc network is a collection of devices equipped with computing and wireless communication capabilities, co-operating together to form a network. An ad-hoc node can communicate with other nodes within its transmission range, or use intermediate nodes to establish communication paths to nodes outside its transmission range. Intermediate nodes in a route can collaborate to act as routers and forward their own traffic as well as the traffic generated by other nodes in a network. This strategy of routing is different to wired networks were communication is made possible through specialised networking devices including hubs, switches and routers interconnecting Local Area Networks (LANs) and Wide Area Networks (WANs). The routers used in LANs and WANs are devices with large processing capabilities, and high speed communication links.

The topology of a network consists of a set of links and nodes which are used to discover and maintain communication paths and assist in coordinating the flow of packets in a network. The topology information can be used for many purposes including evaluating the connectivity/bi-connectivity of a topology and construction of routing paths for network applications. Nodes generally rely on each other to acquire topology information. Topology information can be disseminated by one centralized node by using a specialised process known as 'flooding' or can also be disseminated in a distributed manner by broadcasting partial link state information and generating local topology views. Such local views can be put together to generate a larger topology view of a network.

Topology control is defined as a process where the topology of a network can be controlled by selective addition of nodes and links within a network. This process of selective addition can significantly impact the power usage and connectivity of network devices and improve longevity of a wireless network. In this thesis we analyse the impact of topology control and propose new algorithms and strategies that improve the connectivity, fault tolerance and communication reliability of topology graphs. We review, classify, categorise existing literature and discuss problems and issues associated with topology construction and maintenance proposed with and without Global Positioning System (GPS) aided techniques.

Distributed topology control algorithms proposed for constructing minimum node degree graphs [Bettstetter, 2002] including K-Neigh [Blough et al., 2003], Location Information No Topology (LINT) [Ramanathan and Rosales-Hain, 2000], Location Information Link State Topology (LILT) [Ramanathan and Rosales-Hain, 2000] and MobileGrid (MG) [Liu and Li, 2002], do not necessarily generate bidirectional connected topology graphs and may result in isolated nodes and disconnected clusters. Such isolated nodes and disconnected clusters affect the overall connectivity of a network. The bidirectional connectivity of a network is an important factor in order to determine its performance. A 'bidirectional connected' network, generally known as a connected network, is able to provide access to all crucial parts of a network and allows delivery of applications through a network. The bidirectional links are critical as they facilitate two way communication between the transmitter and receiver nodes. We proposed two mechanisms, Collaborative Algorithm (CA) [Srivastava et al., 2004a] and Probable Critical Links (PCL) [Srivastava et al., 2004d] to improve the connectivity of minimum node degree graphs and analyse their performance [Srivastava et al., 2006].

Power aware topology graphs use low power communications in order to reduce the overall power consumption of network nodes. A power optimised topology graph reduces the total number of links in the topology graph by eliminating long distance links and replacing them with a number of small links. Removing links in a network topology can impact the fault tolerance of a network. Fault tolerance of a network is the ability of a network to cope with link and node failures. We analyse the fault tolerance issues related to power aware topology graphs including Minimum Spanning Tree (MST) [Prim, 1957] and Relative Neighbourhood graphs (RNG) [Huang et al., 2002]. We propose Link Redundancy (LR) algorithm [Srivastava et al., 2005a] to improve the fault tolerance of topology control algorithms. We analyse the performance of LR through worked examples and simulations [Srivastava et al., 2005a]. The LR algorithms yields a higher fault tolerant topology as opposed to the distance based approaches where link selections are made on the basis of the separation distance and may not necessarily yield a higher degree of connectivity [Srivastava et al., 2005a].

Power control also allows nodes to improve the spatial reuse of a wireless channel by reducing interference on other network communications and allowing nodes to communicate simultaneously. We analyse the spatial reuse issues related to topology graphs which can limit the performance of the algorithms due to the presence of hidden nodes [Poon and Li, 2003]. We propose Distributed Range Assignment (DRA) algorithm [Srivastava et al., 2004b] to reduce the hidden nodes in a network topology. We and apply DRA to MST and RNG topology graphs and analyse their performance through worked examples and simulations [Srivastava et al., 2004b].

The distance based topology graphs including MST, RNG, K-Neigh, and CA-PCL [Srivastava et al., 2006] do not model obstacles in a network. The connectivity of distance based topology graphs can be severely limited due to the presence of obstacles as nodes alter transmission range on the basis of the separation distance of links. Including signal attenuation characteristics can construct an accurate view of a network. We analyse the disconnected nature of distance based topology graphs under Lognormal-shadowing [Cox et al., 1984] [Cox et al., 1987] signal attenuation model. The Lognormal-shadowing model is used to analyse the impact of signal strength variations due to shadowing and scattering on the connectivity of power based topology graphs. We propose CA [Srivastava et al., 2006] in conjunction with the with power based topology graphs to improve the connectivity of a network [Srivastava et al., 2005b].

Statement of Originality

This is to certify that the work described in this thesis is entirely my own, except where due reference is made in the text.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed

Gaurav Srivastava
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List of Abbreviations

ABR	Associativity-Based Routing
ACK	Acknowledgment
AODV	Ad-hoc On-demand Distance Vector
AP	Access Point
ARA	Ant-colony-based Routing Algorithm
ARTP	Articulation Point
BS	Base Station
BSS	Basic Service Set
CA	Collaborative Algorithm
CA-PCL	Collaborative Algorithm with Probable Critical Links
CFP	Contention Free Period
CI	Contention Index
CO	Communication Overhead
COMPOW	Common Power Level
CP	Contention Period
CSMA	Carrier Sense Multiple Access
CSMA/CA	Carrier Sense Multiple Access With Collision Avoidance
CTS	Clear To Send
DARPA	Defense Advance Research Project Agency
DBTMA	Dual Busy Tone Multiple Access
DCF	Distributed Coordinate Function
DDR	Distributed Dynamic Routing
DE	Directed Edges

DFS	Depth First Search
DHCP	Dynamic Host Configuration Protocol
DIFS	Distributed Coordinate Function Inter Frame Space
DNS	Domain Name Service
DNTC	Distributed Novel Topology Control Algorithm
DRA	Distributed Range Assignment
DREAM	Distance Routing Effect Algorithm For Mobility
DRNG	Distributed Relative Neighbourhood Graph
DRNG	Distributed Relative Neighbourhood Graph
DS	Distribution System
DSDV	Distance-Sequenced Distance Vector
DSR	Dynamic Source Routing
DSSS	Direct Sequence Spread Spectrum
DST	Distributed Spanning Tree
DT	Delaunay Triangulation
FAMA	Floor Acquisition Multiple Access
FHSS	Frequency Hopping Spread Spectrum
FSR	Fisheye State Routing
GAMA	Group Allocation Multiple Access
GB	Graph Based
GPS	Global Positioning System
GSR	Global State Routing
IEEE	Institute of Electrical and Electronics Engineers
IR	Infra Red
LAN	Local Area Network
LAR	Location Aided Routing
LILT	Location Information Link State Topology
LINT	Location Information No Topology
LMST	Localized Minimum Spanning Tree
LR	Link Redundancy

LR-MST	Link Redundancy Algorithm Applied to Minimum Spanning Tree
LR-RNG	Link Redundancy Algorithm Applied to Relative Neighbourhood Graph
MAC	Medium Access Control
MACA	Multiple Access Collision Avoidance
MACAW	Multiple Access Collision Avoidance For Wireless LAN
MANETs	Mobile Ad-hoc Networks
MG	Mobile Grid
minR	Minimum Radius Graph
MPT	Maximum Power Topology
MST	Minimum Spanning Tree
MST+1	Minimum Spanning Tree Graph with One Additional Link Per Node
NAP	Neighbour Addition Protocol
NAV	Network Allocation Vector
ND	Node Degree
ND-GB	Node Degree Graph Based
ND-PCB	Node Degree Power Control Based
Non-GB	Non Node Degree Graph Based
NonND	Non Node Degree
Non-PCB	Non Node Degree Power Control Based
NRP	Neighbour Reduction Protocol
NTC	Novel Topology Control
OFDM	Orthogonal Frequency Division Multiplexing
OSLR	Optimised Link State Routing
PC	Point Coordinator
PCB	Power Control Based
PCF	Point Coordination Function
PCL	Probable Critical Link
PHY	Physical Layer
PIFS	Point Coordinate Function Inter Frame Space
PL	Pathloss

PL	Power Level
RDMAR	Relative Distance Micro-discovery Ad-hoc Routing
RNG	Relative Neighbourhood Graph
RNG+1	Relative Neighbourhood Graph with One Additional Link Per Node
ROAM	Routing On-demand Acyclic Multipath
RP	Routing Protocol
RTS	Request To Send
SE	Side Effect Edges
SIFS	Short Inter Frame Space
SLURP	Scalable Location Update Routing Protocol
SSA	Signal Stability Adaptive
STAR	Source Tree Adaptive Routing
TB	Tree Based
TBRPF	Topology Broadcast Reverse Path Forwarding
TORA	Temporally Ordered Routing Algorithms
VCS	Virtual Carrier Sensing
WAN	Wide Area Network
WLANS	Wireless Local Area Networks
WRP	Wireless Routing Protocol
ZHLS	Zone Based Hierarchical Link State
ZRP	Zone Routing Protocol